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I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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1.	**Your reference**	8.3.70306/001 — 18 FEB 2000
2.	**Patent application number** *(The Patent Office will fill in this part)*	**0003926.3** — 21FEB00 E514879-1 D00027 P01/7700 0.00-0003926.3
3.	**Full name, address and postcode of the or of each applicant** *(underline all surnames)*	NYCOMED IMAGING AS Nycoveien 2 P.O. Box 4220 Torshov N-0401 Oslo Norway
	Patents ADP number *(if you know it)*	62469610 02
	If the applicant is a corporate body, give country/state of incorporation	Norway
4.	**Title of the invention**	Process for the deprotection of protected thiols
5.	**Name of your agent** *(if you have one)*	Frank B. Dehn & Co.
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	179 Queen Victoria Street London EC4V 4EL AMERSHAM PLC THE ~~AMERSHAM~~ GREAT CENTRAL WHITE LION ROAD AMERSHAM, BUCKINGHAMSHIRE
	Patents ADP number *(if you know it)*	166001

6.	**If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and** *(if you know it)* **the or each application number**	**Country**	**Priority application number** *(if you know it)*	**Date of filing** *(day / month / year)*
				#P79 P51/77 AN 7/3/02.

7.	**If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application**	**Number of earlier application**	**Date of filing** *(day / month / year)*

8.	**Is a statement of inventorship and of right to grant of a patent required in support of this request?** *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Description	13
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Priority documents	-
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	-
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. **I/We request the grant of a patent on the basis of this application.**

Frank B. Dehn & Co. - Agents for the Applicant

Signature **Date** 18 February 2000

12. **Name and daytime telephone number of person to contact in the United Kingdom**

J.C. Marsden
020 7206 0600

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70306/001.608

Process for the deprotection of protected thiols

This invention relates to a new process for the deprotection of protected thiol compounds, more particularly thiols protected by acetamidomethyl, 4-methylbenzyl and t-butyl groups (hereinafter referred to as Acm, MBzl and tBu respectively), with concomitant oxidation of the deprotected thiols to form disulphides. Such processes are particularly useful in peptide synthesis.

During organic syntheses it is quite routine for certain reactive functionalities to be protected to prevent their participation in unwanted side reactions. For example, reactive carbonyl functionalities are often protected as ketals, and reactive hydroxyl and carboxyl groups are often protected as esters.

The neutral but strongly nucleophilic thiol group present in cysteine generally requires protection during peptide syntheses. A wide variety of thiol protecting groups are known, including benzyl, MBzl, 4-methoxybenzyl, trityl, methoxytrityl, tBu, t-butylthiol, acetyl, 3-nitro-2-pyridinesulphenyl and Acm. All these groups have been successfully used in peptide synthesis and are reviewed by Barany and Merrifield in "The Peptides" Vol. 2, Ed. Gross and Minehoffer, Academic Press, pp. 233-240 (1980).

Acm is a thiol protecting group which is normally removed by oxidative cleavage, for example by treatment with mercury (II), iodine, silver (I) or thallium (III). It is generally regarded as acid stable since, although acidolytic cleavage of Acm is theoretically possible in anhydrous or aqueous acids, such reactions are inconveniently slow in practice because of difficulties in protonating the sulphur atom.

In this context Fujii *et al.* in Chem. Pharm. Bull.

41(6), pp. 1030-1034 (1993) describe the synthesis and oxidation of oxytocin using Cys(Acm) and trifluoroacetic acid (TFA)/10% dimethyl sulphoxide (DMSO). The authors state that Cys(Acm)-oxytocin survived nearly intact after a 12 hour treatment in the above TFA/DMSO mixture, showing that Acm protection is stable under such acid conditions. The S-Acm group was also reported by Veber *et al.* in J. Am. Chem. Soc. **94**, pp. 5456-5461 (1972) as being stable to hydrofluoric acid (HF) and strong nucleophiles such as hydrazine.

Van Rietschoten *et al.* reported in Peptides (1977), pp. 522-524 that treatment of a peptide containing four Acm groups with HF-anisole resulted in 20% of the Acm groups being removed. More recently, Fisher *et al.* in J. Pep. Res. **49(4)**, pp. 341-346 (1997) have described a modification to a tyrosine residue due to acidolytic cleavage of Acm, and Singh *et al.* in Tetrahedron Letters Vol. 37, No. 24, pp. 4117-4120 (1996) report on the partial acidolytic cleavage of Acm from C-terminal Cys(Acm) peptides. These acid-induced deprotection reactions are regarded as unwanted side reactions during peptide cleavage.

The MBzl thiol protecting group is traditionally cleaved using strong acids such as HF at a temperature of -5°C to 0°C. Otaka *et al.* in Tetrahedron Letters Vol. 32, No. 9, pp. 1223-1226 (1991) report that the MBzl group is stable to TFA and that MBzl-protected cysteine is not converted to cystine upon treatment with TFA/10% DMSO at room temperature.

The tBu thiol protecting group is typically removed by oxidative cleavage, e.g. by treatment with mercury (II), or by acidolysis with trifluoromethane sulphonic acid. The group is considered to be stable to TFA and to iodine oxidation.

Although Akaji *et al.* in J. Am. Chem. Soc., Vol. 114, No. 11, pp. 4137-4143 (1992) report the acidolytic removal of a variety of cysteine protecting groups

including MBzl, tBu and Acm, the reaction is dependent on the presence of a suitable silyl chloride.

The present invention is based on the unexpected finding that Acm, MBzl and tBu thiol protecting groups are labile to acids under oxidising conditions, particularly as the reaction temperature is increased. Thus tBu thiol protecting groups may be rapidly cleaved in this way at room temperature and even more rapidly at elevated temperatures. Acm and MBzl thiol protecting groups become increasingly labile under such conditions at temperatures in excess of 30°C, particularly at temperatures of 50°C and above, such that it is possible to achieve substantially quantitative deprotection with reaction times of a few hours or less. Such acid-induced deprotection is particularly advantageous in that it avoids the need for use of the more toxic reagents currently employed to remove Acm, MBzl and tBu groups. By conducting the deprotection in the presence of an oxidising agent the liberated thiol groups are converted directly to intermolecular or intramolecular disulphide groups; as discussed hereinafter this has particularly valuable applications in the synthesis of cyclic peptides containing disulphide linkages.

Thus, according to one aspect, the invention provides a process for the deprotection of an Acm-, MBzl- and/or tBu-protected thiol which comprises reacting said protected thiol with an acid in the presence of an oxidising agent at a temperature sufficient to effect deprotection and generation of disulphide bonds.

Both aqueous and anhydrous acids may be used in the process. Thus, for example, aqueous inorganic acids, e.g. mineral acids such as hydrochloric acid, and aqueous or anhydrous organic acids, e.g. carboxylic acids such as acetic acid or, more preferably, strong carboxylic acids such as TFA, and sulphonic acids such as methanesulphonic acid may be useful.

DMSO is a preferred example of an oxidising agent useful in the process. Other sulphoxides such as tetramethylenesulphoxide may also be useful, as may metal superoxides and peroxides such as potassium superoxide or nickel peroxide, thiocarbonates such as sodium trithiocarbonate and organometallic carbonates such as triphenylbismuth carbonate.

In a preferred embodiment the thiol to be deprotected is a peptide containing one or more Acm-, MBzl- and/or tBu-protected cysteine residues.

Peptides represent a class of molecules which are extremely well suited for the targeting of disease specific markers *in vivo*, and considerable attention is being given to the preparation of synthetic peptides as potential components of targeted imaging agents.

The synthesis of cysteine-containing peptides presents special challenges to a peptide chemist as the peptide can exist in either a reduced or an oxidised state. Oxidised peptides containing more than one cysteine residue may form intramolecular disulphides or intermolecular disulphides such as dimers, trimers or multimers. Thus, for example, a peptide containing six cysteine residues is potentially capable of forming 15 disulphide isomers, and careful planning and selection of suitable protection strategy is therefore required if correct disulphide pairings are to be achieved in such peptides. It will be appreciated that correct pairing is frequently critical to correct folding of the peptide backbone and concomitant orientation of side chain functionalities in order to give a biologically active conformation capable of high affinity receptor binding.

Typical existing strategies for the selective formation of two or more disulphide bonds use combinations of protecting groups such as trityl and Acm or t-butylthio and Acm, the first disulphide bond being formed after removal of the trityl or t-butylthio groups and the second being formed by oxidative cleavage of the

Acm groups using, for example, iodine or thallium trifluoroacetate. Other examples of the synthesis of multibridged peptides include the solution synthesis of insulin by Sieber *et al.* described in Helv. Chim. Acta. **57**, pp. 2617-2621 (1974) and the procedures of Atherton *et al.*, J. Chem. Soc. Perkin Trans. **1**, p. 2065 (1985) and Akaji *et al.*, J. Am. Chem. Soc. **115**, p. 11384 (1993).

Deprotection in accordance with the present invention permits considerable simplification of such strategies, such that two or more disulphide bonds may be generated in a "one pot" reaction, thereby avoiding the need for intermediate purification of partially oxidised or partially protected peptides and so achieving savings in solvent use and time and improvements in product yield. Thus, by preparing a peptide containing two acid-labile thiol protecting groups (e.g. trityl groups) as well as two or more Acm and/or MBzl groups, a first disulphide bond may be formed by acid treatment of the peptide at a relatively low (e.g. ambient) temperature and one or more further disulphide bonds may be formed simply by increasing the temperature of the reaction mixture to a temperature in excess of 30°C such that the Acm and/or MBzl groups are cleaved. The required oxidising agent may be added before or after the low temperature treatment, as desired.

The positions of the acid-labile protecting groups are advantageously such that the first-formed disulphide bond brings the molecule into a folded conformation such that the remaining Acm-protected and/or MBzl-protected thiol groups are juxtaposed in a manner which facilitates correct formation of the remaining disulphide bond or bonds.

Since, as noted above, tBu thiol protecting groups are readily cleaved at room temperature by acidic and oxidative treatment, a combination of tBu with Acm

and/or MBzl protection may be used, with the tBu groups being cleaved at room temperature and the Acm and/or MBzl groups subsequently being removed upon heating to a temperature above 30°C. The specific formation of multiple disulphides may therefore be effected in high yield using a "one pot" strategy without the need for isolating intermediates by chromatography.

The use of TFA/DMSO mixtures, e.g. with a DMSO content of 1 to 20%, e.g. 2-10%, to promote deprotection and disulphide bond formation is particularly preferred in such embodiments of the invention, since both the S-protected starting materials and the disulphide linked intermediates and end products will typically be soluble in such mixtures. Both TFA and DMSO may readily be recycled for further use.

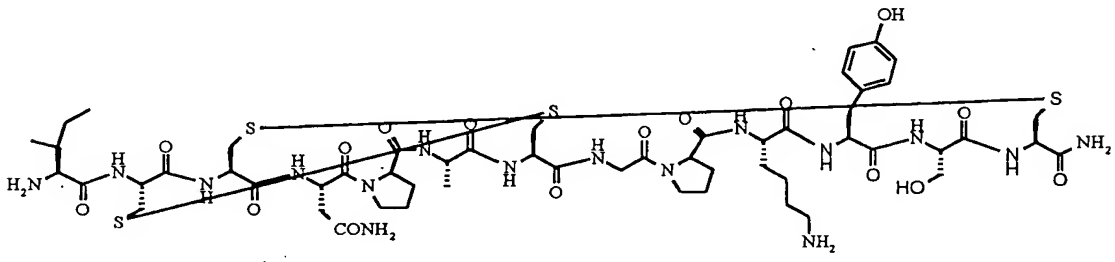
The fact that thiol protecting groups such as trityl and methoxytrityl are generally acid labile, whilst tBu thiol protecting groups are only acid labile under oxidising conditions may be exploited in the synthesis of peptides containing three disulphide bonds by a regioselective "one pot" oxidation process. Thus a resin-supported synthetic peptide containing appropriately positioned pairs of cysteine residues protected with trityl, methoxytrityl or other acid labile groups, with tBu groups and with Acm and/or MBzl groups repectively may initially be treated with acid to effect cleavage from the resin and cleavage of the trityl, methoxytrityl or other acid labile protecting groups. The thus-generated pair of thiol groups may be oxidised in aqueous solution at basic pH or in aqueous DMSO to form the first desired disulphide bond, whereafter the solvent may be evaporated *in vacuo* or by freeze drying. Successive low (e.g. room) temperature and high (i.e. >30°C) temperature acidic and oxidative treatment of the product as described above then leads to formation of the desired second and third disulphide bonds by successive reaction of the tBu-protected and

Acm- and/or MBzl-protected pairs of thiol groups.

The present procedure allows cysteine-containing peptides to be oxidised at concentrations in excess of 1 mg/ml, thereby substantially reducing solvent volume requirements compared to existing protocols such as iodine cleavage of Acm and air oxidation, which typically employ peptide concentrations of the order of 0.1 mg/ml and so require the product to be concentrated, e.g. by ion exchange chromatography, prior to final purification. In accordance with the present procedure, on the other hand, product concentration may be effected simply by solvent evaporation *in vacuo*.

The following non-limitative Examples serve to illustrate the invention.

Example 1: "One pot" synthesis of α-conotoxin SI [Ile-Cys-Cys-Asn-Pro-Ala-Cys-Gly-Pro-Lys-Tyr-Ser-Cys-NH_2. with disulphide bonds connecting Cys 2 with Cys 7 and Cys 3 with Cys 13]



The peptide sequence was assembled on an ABI 433A automatic peptide synthesiser starting with Rink amide resin (Novabiochem) on a 0.12 mmol scale using 1 mmol amino acid cartridges. Cysteine residues 2 and 7 were protected with trityl groups, while residues 3 and 13 were protected with acetamidomethyl groups. All amino acids were pre-activated using *O*-Benzotriazol-1-yl-*N,N,N',N'*-tetramethyluronium hexafluorophosphate (HBTU).

Simultaneous removal of the peptide from the resin and the side-chain protecting groups (except Acm) from the peptide was effected by treatment with trifluoroacetic acid (TFA) containing 5% triisopropylsilane and 5% water for 2 hours, giving a crude product yield of 130 mg. HPLC analysis of the crude product (Vydac 218TP54 column) was carried out using a gradient of 5 to 30% B over 20 minutes (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) at a flow rate of 1 ml/minute; the product was found to be >90% pure. Further product characterisation was carried out using MALDI mass spectrometry: M+H for Acm protected product expected at 1496, found at 1502.

To 2 mg of the crude product were added TFA (10 ml) and dimethyl sulphoxide (DMSO) (0.1 ml). The mixture was stirred on ice and the course of oxidation was followed by HPLC. The starting product, retention time 16.2 minutes (0 to 30% B over 20 minutes where A = 0.1%

TFA/water and B = 0.1% TFA/acetonitrile), was slowly replaced by a new product with a retention time of 16.4 minutes, and after 2 hours the starting product had completely disappeared. 0.05 ml of anisole was then added to the peptide solution, and the mixture was warmed to 60°C for a further 2 hours, whereafter the TFA was removed *in vacuo* and the peptide was precipitated by the addition of diethyl ether. The crude fully oxidised material (1.4 mg) comprised 2 main products, ratio 1:5, with HPLC retention times of 16.9 and 17.8 minutes respectively. The 17.8 minute product, comprising *ca.* 80% of the material, was found to co-elute with an authentic sample of α-conotoxin (Bachem, H-1112).

Purification on a Vydac 218TP152010 semi-preparative column using a gradient of 0 to 30% B over 30 minutes (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) at a flow rate of 5 ml/minute, followed by freeze-drying, afforded conotoxin (0.7 mg, 35% yield) which was found to be >90% pure. Further characterisation was carried out using MALDI mass spectrometry: M+H for product expected at 1354, found at 1356.

Example 2: "One pot" synthesis of α-conotoxin SI

The peptide sequence was assembled as described in Example 1 except that cysteine residues 2 and 7 were protected with t-butyl groups, while residues 3 and 13 were protected with 4-methylbenzyl groups. All amino acids were pre-activated using HBTU.

Simultaneous removal of the peptide from the resin and the side-chain protecting groups (except t-butyl and 4-methylbenzyl) from the peptide was effected by treatment with TFA containing 5% triisopropylsilane and 5% water for 2 hours, giving a crude product yield of 125 mg. HPLC analysis of the crude product (Vydac 218TP54 column) was carried out using a gradient of 20

to 60% B over 20 minutes (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) at a flow rate of 1 ml/minute; the product was found to have a retention time of 15.7 minutes and purity >90%. Further product characterisation was carried out using MALDI mass spectrometry: M+H for partially protected product expected at 1680, found at 1685.

To 50 mg of the crude partially protected product in a clean flask were added TFA (98 ml), DMSO (2.0 ml) and anisole (0.1 mL). The mixture was stirred at room temperature for 40 minutes and a sample of the reaction mixture was run on a MALDI mass spectrometer. A new product appeared which was confirmed to be the single disulphide with the 4-methylbenzyl protecting groups remaining: M+H for partially protected product expected at 1565, found at 1568.

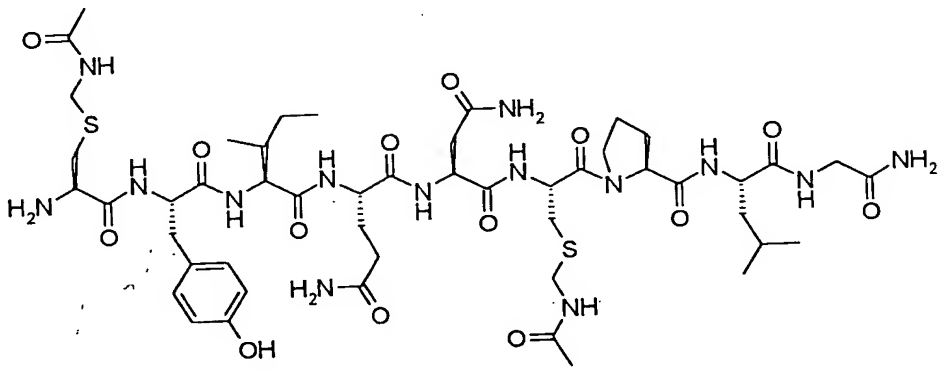
The flask was then placed in an oil bath and heated to 70°C for 3 hours, following which the TFA was removed *in vacuo* and the peptide was precipitated by the addition of diethyl ether. The precipitate was trituratyed with ether and air-dried to give crude fully oxidised product (45 mg) in almost quantitative yield and with an HPLC purity of >90%.

An aliquot of 20 mg of the crude fully oxidised product was purified by preparative HPLC on a Vydac 218TP1022 C18 preparative column using a gradient of 0 to 30% B over 40 minutes (A = 0.1% TFA/ water and B = 0.1% TFA/ acetonitrile) at a flow rate of 9 ml/minute. The fractions containing pure product were collected and freeze-dried (10 mg, 50% yield). The product was found to be >99% pure by analytical HPLC. Further characterisation was carried out using MALDI mass spectrometry: M+H for product expected at 1354, found at 1356.

The material was shown to co-elute with an authentic sample of α-conotoxin (Bachem, H-1112).

Example 3: Synthesis of oxytocin

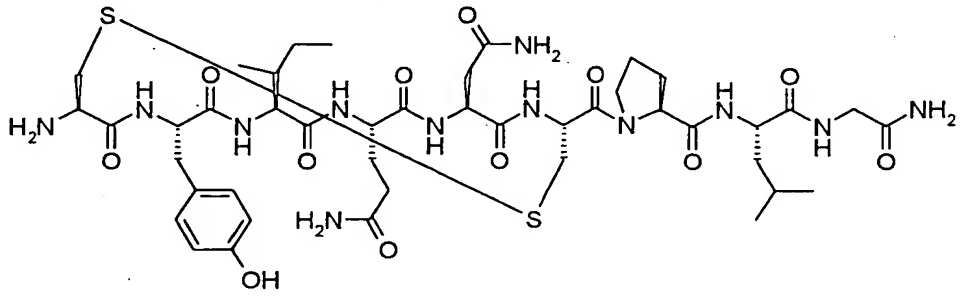
a) Synthesis of Cys(Acm)-protected oxytocin: NH_2-Cys(Acm)-Tyr-Ile-Gln-Asn-Cys(Acm)-Pro-Leu-Gly-NH_2



The peptide was synthesised on a ABI 433A automatic peptide synthesiser starting with Rink amide AM resin on a 0.25 mmol scale using 1 mmol amino acid cartridges. The amino acids were pre-activated using HBTU before coupling. Simultaneous removal of the peptide from the resin and the side-chain protecting groups (except Acm) from the peptide was effected by treatment with TFA containing 5% triisopropylsilane and 5% water for one hour.

The resulting crude naterial (300 mg) was purified by preparative HPLC (Vydac C18 218TP1022 column) using a gradient of 5 to 30% B over 40 minutes (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) at a flow rate of 9 ml/minute. After lyophilization 166 mg of pure material was obtained. HPLC analysis of this purified product (Vydac C18 218TP54 column) was carried out using a gradient of 5 to 50% B (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) with product detection by UV at 214 nm; the product retention time was 14.30 minutes. Further product characterisation was carried out using MALDI mass spectrometry: M+H for product expected at 1151.0, found at 1551.5.

b) Deprotection and oxidation to form oxytocin [NH_2-Cys-Tyr-Ile-Gln-Asn-Cys-Pro-Leu-Gly-NH_2, with disulphide bond connecting Cys 1 with Cys 6]



5 mg of Cys(Acm)-protected oxytocin was dissolved in TFA (2 ml) then added to a mixture of anisole (40 μl), DMSO (1 ml) and TFA (18 ml) preheated to 60°C. After 5 hours at this temperature the occurence of quantitative conversion to oxytocin was confirmed by analytical HPLC (Vydac C18 218TP54 column) using a gradient of 5 to 50% B (A = 0.1% TFA/water and B = 0.1% TFA/acetonitrile) with product detection by UV at 214 nm; the product retention time was 12.98 minutes. Further product characterisation was carried out using MALDI mass spectrometry: M+H for product expected at 1007, found at 1011. The product was found to co-elute with an authentic sample of oxytocin purchased form Novabiochem.

Example 4: Comparative study of deprotection and oxidation rates of cysteine-protected oxytocin analogues at room temperature and 60°C

The procedure of Example 3(a) was repeated to prepare Cys(tBu)-protected and Cys(MBzl)-protected analogues of oxytocin. Deprotection and oxidation of these analogues and Cys(Acm)-protected oxytocin were carried out as described in Example 3(b) at room temperature and at 60°C. The following table summarises the extent of conversion to oxytocin as determined by analytical HPLC; the occurence of quantitative

conversion at 60°C was confirmed by MALDI mass spectrometry.

Protecting group	% oxytocin formed at room temperature	% oxytocin formed at 60°C
tBu	100% after 40 min.	100% after 10 min.
Acm	45% after 72 hours	100% after 5 hours
MBzl	30% after 72 hours	100% after 6 hours